Registration of 'CPCL 05-1102' Sugarcane

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ABSTRACT

'CPCL 05-1102' (Reg. No. CV-157, PI 667556) sugarcane (a complex hybrid of *Saccharum* spp.) is the product of research initiated by the United States Sugar Corporation (USSC) and completed cooperatively by the USDA-ARS, the University of Florida, and the Florida Sugar Cane League, Inc. CPCL 05-1102 was released to growers in Florida on 16 Oct. 2012. CPCL 05-1102 was selected from a cross between the USSC proprietary cultivars CL 89-5189 (female) and CL 88-4730 (male) made at Clewiston, FL on 18 Dec. 2000. CL 89-5189 was adapted to muck soils, where it was used only briefly in commercial plantings of USSC due to yield losses to ratoon stunt (caused by *Leifsonia xyli* subsp. *xyli*). CL 88-4730 is widely used on commercial plantings of USSC, particularly on sand soils. CPCL 05-1102 has acceptable resistance to leaf scald (caused by *Xanthomonas albilineans* Ashby, Dowson), *Sugarcane mosaic virus* strain E (mosaic), smut (caused by *Ustilago scitaminea* Sydow & P. Sydow), orange rust (caused by *Puccinia kuehnii* E.J. Butler), and brown rust (caused by *Puccinia melanocephala* H. & P. Sydow). *Bru*1, a major gene for resistance to brown rust, was not detected in the DNA of CPCL 05-1102. CPCL 05-1102 has high cane and sucrose yields and excellent freeze tolerance and is expected to be used on muck soils in Florida.

The United States Sugar Corporation (USSC) previously released proprietary sugarcane cultivars with the prefix CL in its long-term recurrent breeding and selection program. 'CPCL 05-1102' (Reg. No. CV-157, PI 667556), a complex hybrid of sugarcane (*Saccharum* spp.), is a product of the USSC breeding program. Final selection for release was made through cooperative research of the USDA-ARS, the University of Florida, and the Florida Sugar Cane League, Inc. Collectively this program is referred to as the Canal Point (CP) sugarcane cultivar breeding and selection program (CP program) because its base of operations is at Canal Point, FL. Sugarcane cultivars developed through crossing and selection within the CP program have a "CP" prefix. The CPCL prefix of CPCL 05-1102 indicates that it was crossed in the USSC program in Clewiston and that final selection occurred in the CP program. CPCL 05-1102 was publicly released in Florida on 16 Oct. 2012.

Sugarcane in Florida is grown on muck and sand soils. The muck soils comprised 80.3% of the total sugarcane area, and the sand soils the remaining 19.7% in 2011 (Rice et al., 2012). For more than 30 yr, the CP program was more successful at identifying new high-yielding cultivars for the muck than for the sand soils (Edmé et al., 2005). Recently, several researchers have worked on resolving this issue (Glaz and Kang, 2008; Glynn et al., 2009a; del Blanco et al., 2010; Zhao et al., 2010). Although CPCL 05-1102 was released for muck soils, there has been recent progress in addressing the need for new high-yielding cultivars on sand soils with the registrations of CP 03-1912 (Gilbert et al., 2011) and CP 04-1566 (Comstock et al., 2013).

CPCL 05-1102 was released because of its high sucrose yields and cane yields on muck soils, its excellent tolerance to freezing temperatures, and its resistance to brown rust (caused by *Puccinia melanocephala* Syd. & P. Syd.), orange rust (caused by *Puccinia kuehnii* (W. Krüger) E.J. Butler), leaf scald (caused by *Xanthomonas albilineans* Ashby, Dowson), *Sugarcane mosaic virus* strain E (mosaic), and smut (caused by *Ustilago scitaminea* H. & P. Sydow). CPCL 05-1102 was tested on muck soils only in the final testing stage of the CP program and is recommended only for Florida growers with muck soils.

CPCL 05-1102 was selected from the cross CL 89-5189 × CL 88-4730 made at Clewiston, FL on 18 Dec. 2000. CL 89-5189, the female parent of CPCL 05-1102, is a

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Abbreviations: CP, Canal Point; CRS, commercial recoverable sucrose; SCYLV, *Sugarcane yellow leaf virus*; TRS, theoretical recoverable sucrose; USSC, United States Sugar Corporation.

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proprietary cultivar of USSC with a large stalk size that is best adapted to muck soils. It has not been used widely due to its susceptibility to ratoon stunt (caused by *Leifsonia xyli* subsp. *xyli*). The male parent of CPCL 05-1102, CL 88-4730, is a proprietary cultivar that USSC uses extensively on sand soils in Florida. CP 72-1210 (MIA 34313; Miller et al., 1981) was a grandparent of CPCL 05-1102 on the female side and a great-grandparent on the male side (Fig. 1). CP 65-357 (CANE 9904; Breaux et al., 1974) was the female parent of CP 72-1210. CP 72-1210 was widely grown in Florida on muck and sand soils, peaking at 61% of the total sugarcane hectarage in Florida in 1987 (Glaz and Coale, 1987). CP 65-357 was also a major cultivar in Florida, but it was much more widely grown in Louisiana, where it peaked with 71% of the total sugarcane hectarage in 1982 (Fanguy, 1983).

The true seed of CPCL 05-1102 was planted at the USSC experimental trial site at Ritta Farm, about 15 km from Clewiston, FL in June 2003. The CP program begins numbering its annual stage-1 selections at 1001. In 2005, the CP program assigned numbers 1001 through 1360 for selections in stage 1 that originated from seedlings planted on a muck soil at Ritta Farm in the USSC program, numbers 1361 through 1750 for stage-1 selections that originated from seedlings on a muck soil planted at Canal Point in the CP program, and numbers 1751 through 1811 for selections in stage 1 that originated from seedlings on a sand soil planted at Townsite Farm in the USSC program. Thus, the number 1102 in the name CPCL 05-1102 indicates that this cultivar was the 102nd genotype selected in stage 1 planted at Canal Point and that it originated from seedlings in the USSC program planted at Ritta Farm, and "05" in the name indicates that it was planted in stage 2 at Canal Point in the year 2005. "CL" in CPCL indicates that the original seed for this cultivar came from a cross made in the USSC breeding program in Clewiston, Florida. "CP" indicates that some of the selection (in this case all of the selection after the seedling stage) on CPCL 05-1102 was completed in the CP program.

Methods

Early Selection Stages at USSC

On 18 Dec. 2000, at USSC in Clewiston, FL, flowers from CL 89-5189 and CL 88-4730 were crossed. The resulting F_1 seeds were planted in flats in a greenhouse early in 2003. In June 2003, 44,018 seedlings were transplanted to a Terra Ceia muck soil at Ritta Farm of USSC, and 481 of these seedlings were siblings of CPCL 05-1102. Proprietary USSC cultivars CL 77-797 and CL 90-4725 along with CP 80-1743 (Deren et al., 1991) and CP 89-2143 (Glaz et al., 2000) were planted as reference cultivars. Plants were spaced 0.8 m apart and row spacing was 3 m. From this stage on, CPCL 05-1102 and all other genotypes were propagated clonally. Visual selection for biomass (based on stalk number, and stalk size, solidness, and lack of pith) was conducted in the first-ratoon crop of these seedlings in October 2004.

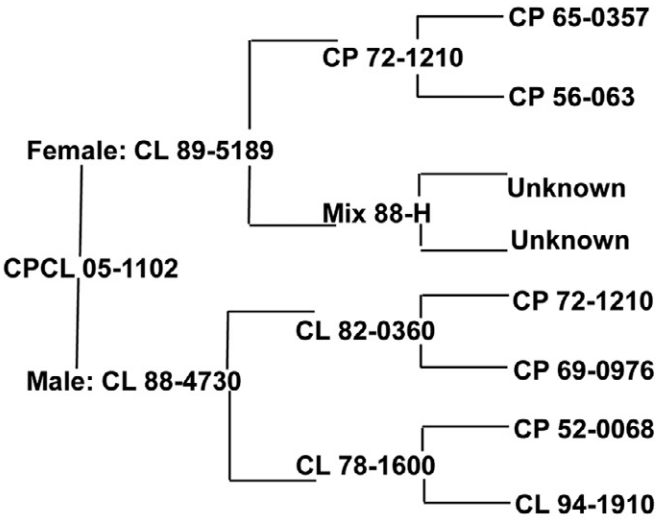

Figure 1. Pedigree chart showing parents and known grandparents and great-grandparents of CPCL 05-1102.

Advancement of CPCL 05-1102 in the Canal Point Program

In October 2004, CPCL 05-1102 was donated by the USSC to the USDA-ARS at Canal Point, where it was planted in stage 1 with a total of 12,125 unreplicated genotypes. Stage-1 plots comprised one row, which was 1.2 m long, and were separated by 1.2-m alleys. As in all subsequent selection stages, row spacing was 1.5 m. Selection in stage 1 was visual with emphasis placed on vigor and resistance to natural infections of brown rust, smut, and leaf scald.

There were 1320 genotypes, including CPCl 05-1102, advanced to stage 2 at Canal Point in November 2005. Stage-2 plots consisted of two rows that were 4.5 m long. The stage-2 plots were arranged in sections and each section was two plots long. The two plots within each section were separated in the middle of the section by a 1.5-m alley. The end of one section was separated from the beginning of the following section by a 6.0-m alley. CP 72-2086 (Miller et al., 1984), CP 78-1628 (Tai et al., 1991), and CP 89-2143 were the reference cultivars in stage 2. CP 72-2086 and CP 89-2143 were each replicated 18 times, and CP 78-1628 was replicated 15 times. The stage-2 plots were rated visually for growth habit, agronomic traits, and natural infection of diseases. The aim of the selection team conducting these visual selections was to minimize genotypes that were excessively recumbent or had problems such as protruding buds or broken stalks.

Stalks were counted in stage 2 in August 2006. In the second week of October 2006, a sample of 10 stalks was collected from each plot and weighed. Cane yield (*C*) was calculated as the product of stalk weight by stalk number:

$$C\ (\text{Mg ha}^{-1}) = \text{stalk weight (kg stalk}^{-1}) \times \text{stalk number (stalks ha}^{-1}) \div 1000$$

Each 10-stalk sample was milled immediately after being weighed, and the theoretical recoverable sucrose (TRS) concentration was determined on the extracted juice

as described by Legendre (1992). The fiber concentration used in this formula was 100 g fiber kg^{-1} cane for all genotypes in stages 2 and 3 and estimated separately for each genotype as described later in stage 4. Each value of TRS was multiplied by 0.86 to approximate commercial recoverable sucrose (CRS). The value of 0.86 was determined based on unpublished data of the sample mill at Canal Point. Legendre (1992) reported the calculation of similar liquidation factors (ranging from 0.83 to 0.90) used by commercial mills in Louisiana to convert TRS to CRS. The theoretical economic index (profitability) of each genotype was calculated based on a procedure that integrated CRS and the costs of harvesting, hauling, and milling sugarcane in Florida (Deren et al., 1995). The major selection criteria in stage 2 and later in stages 3 and 4 were profitability, sucrose yield, and resistance to diseases (primarily brown rust, orange rust, mosaic, smut, and leaf scald).

The committee in Florida that evaluates sugarcane genotypes in the CP selection program advanced 135 genotypes from stage 2 to stage 3 in November 2006 (Table 1). Of these 135 genotypes, CPCL 05-1102 ranked 55th for stalk number, 57th for stalk weight, 32nd for cane yield, 7th for CRS, 2nd for sucrose yield, and 2nd for economic index. Based on these rankings and its observed resistance to major sugarcane diseases, CPCL 05-1102 was among the 135 genotypes planted in November 2006 in stage 3 on muck and sand soils. In the CP program, stage 3 is the first replicated selection stage, the first stage conducted on multiple environments, the first stage conducted in commercial fields, and the first stage conducted in a ratoon crop. The four commercial farms, representative of the Florida sugarcane growing area were A. Duda & Sons, Inc. (26°35.93′ N, 80°37.81′ W), Okeelanta Corporation (26°34.35′ N, 80°49.72′ W), and Sugar Farms Cooperative North–Osceola Region (26°50.53′ N, 80°31.93′ W), which had organic (muck) soils, and Hilliard Brothers of Florida Ltd. (26°42.14′ N, 81°2.31′ W), which had a sand soil. Each trial had two replications of each genotype planted in a randomized complete block design in plot configurations with sections as described for stage 2. Data were collected in the plant-cane (October 2007 and January 2008) and first-ratoon (October 2008) crops. The commercial reference cultivars were CP 72-2086, CP 78-1628, and CP 89-2143. Estimates of cane and sucrose yields and profitability were determined according to procedures described for stage 2.

The committee that makes decisions on genotypes in the CP program advanced 19 genotypes to stage 4 in November 2008. Of these, 7 genotypes were planted at all 10 locations in stage 4, 6 exclusively on the 7 farms in stage 4 with muck soils, and the remaining 6 genotypes were planted only at the three farms in stage 4 with sand soils. CPCL 05-1102 was one of the six genotypes planted only at the seven farms with muck soils in stage 4.

Five of the seven stage-4 trials including CPCL 05-1102 were planted on commercial fields in November and December 2008. The trial sites included three trials at the same three farms with muck soils used for stage 3 plus two more locations with muck soils. The sites with muck soils were A. Duda & Sons, Inc. (26°36.82′ N, 80°37.40′ W), Knight Management, Inc. (26°38.53′ N, 80°27.21′ W), Okeelanta Corporation (26°35.37′ N, 80°43.90′ W), Sugar Farms Cooperative North-SFI Region (26°43.07′ N, 80°27.55′ W), and Wedgworth Farms, Inc. (26°40.73′ N, 80°34.37′ W). Two stage-4 trials including CPCL 05-1102 were planted in 2009 on farms with muck soils, Eastgate Farms, Inc. (26°47.67′ N, 80° 39.97′ W) and Okeelanta Corporation (26°39.67′ N, 80°73.18′ W).

Three reference cultivars were planted at all locations; however, the primary reference cultivars for muck soils were CP 72-2086 and CP 89-2143. CP 78-1628 was also a reference cultivar, and although it was planted at the stage-4 locations with muck soils, it was used primarily for comparing yields of new genotypes at locations with sand soils. Each trial had six replications with genotypes planted in a randomized complete block design with plots three rows wide and 10.5 m long. Alleys of 1.5 m separated plots. Experiments were two plots wide and 48 plots long.

For the five trials planted in 2008, stalks were counted in the two interior rows of each plot from July through September in 2009 (plant cane), 2010 (first ratoon), and 2011 (second ratoon). Cane tonnage was estimated by multiplying the stalk weight by the stalk number and converting the value to a per hectare basis. Stage-4 trials were sampled from October through March to represent the range in commercial harvest dates for sugarcane in Florida. Generally, second-ratoon trials were harvested

Table 1. Summary of the decision process leading to the release of sugarcane cultivar CPCL 05-1102 in Florida.

Year	Month	Stage and advancement information	Genotypes in stage	Locations
2000	December	Cross made at United States Sugar Corporation (USSC)	—	Clewiston, FL
2003	June	Germinated true seed transplanted into field (seedlings)	44,018	Ritta Farm, USSC
2004	October	CL 05-1102 donated from USSC to USDA-ARS at Canal Point, FL; name changed to CPCL 05-1102	31,587	—
2004	October	Planted in stage 1 (unreplicated)	12,125	Canal Point, FL
2005	November	Planted in stage 2 (unreplicated)	1,320	Canal Point, FL
2006	November–December	Planted in stage 3 (2 replications)	135	4 farms in Florida
2007	November–December	Planted as one of most promising based on stage 3 plant-cane data (unreplicated)	40	10 farms in Florida
2008	November–December	Planted in stage 4 on muck soils (6 replications)	13	10 farms in Florida
2012	October	Cultivar release	1	

first, followed by first-ratoon and plant-cane trials. Stalk weight and CRS were estimated, as described for stage 2, from a 10-stalk sample collected from the middle row of each plot from October through March of 2009–10 (plant cane), 2010–11 (first ratoon), and 2011–12 (second ratoon) except that the historical fiber concentrations of CP 72-2086 (89.7 g kg^{-1}; Miller et al., 1984) and CP 89-2143 (98.5 g kg^{-1}; Glaz et al., 2000) were used in their CRS calculations, and the estimated fiber concentration of CPCL 05-1102 was used in its CRS calculations. For the two stage-4 trials planted in 2009, all activities occurred in the same months 1 yr later, except that stalk counting occurred at Eastgate Farms, Inc. in June 2010 for the plant-cane crop.

During the 4-yr period when it was in stage 4, 15 samples of CPCL 05-1102 were processed for analysis of fiber concentration. Each sample consisted of three stalks and was collected from border rows of stage-4 plots or from stage-3 plots that were no longer being used for yield estimation. When a fiber sample was collected from a border row, we did so to avoid affecting rows used for yield estimation. After the leaves were removed, the stalks were shredded through a Jeffco cutter-grinder (Jeffries Brothers, Ltd.). Between 390 and 410 g of shredded material were collected, weighed, and pressed at 138 MPa for 30 s. Degrees Brix were measured on the juice that was extracted from the pressed material with a handheld refractometer. The pressed samples were weighed, crumbled, placed in paper bags, and dried at 60°C to a constant weight. Fiber percentages were calculated as described by Tanimoto (1964). Samples of a reference cultivar and CPCL 05-1102 were processed on the same dates. All fiber percentages calculated on a given day were corrected to the historic fiber concentration of the reference cultivar. For example, the historic fiber concentration of CP 89-2143 was 98.5 g fiber kg^{-1} cane. If the estimated fiber concentration of CP 89-2143 was 100.0 g kg^{-1} on the day that a set of samples for CPCL 05-1102 was processed, then the estimated fiber concentration of CPCL 05-1102 would have been multiplied by 0.985 to correct it to the historical fiber concentration of CP 89-2143. The most updated mean of corrected fiber concentrations of CPCL 05-1102 was used each year in the formula reported by Legendre (1992) for calculating its CRS.

Agronomic and Botanical Descriptions

Data for the agronomic and botanical descriptions of CPCL 05-1102 were recorded on 10 mature stalks sampled on 1 Aug. 2012, 338 d after planting on a Torry muck soil at Eastgate Farms near Pahokee, FL. Stalks were sampled from the inner rows of a planting and the agronomic and botanical characteristics were recorded based on descriptions in Artschwager and Brandes (1958). Colors were characterized according to the Munsell color charts (Munsell Color Co., 1977). Stalks of CPCL 05-1102 were compared with those of CP 89-2143 that were planted in the same field on the same date.

Table 2. Size range and number of fragments generated by each of six microsatellite primer pairs from sugarcane cultivars CP 72-2086, CP 78-1628, CP 80-1743, CP 84-1198, CP 89-2143, and CPCL 05-1102.

Primer name	Size range of fragments	Number of fragments		
		Total (all six cultivars)	From CPCL 05-1102	
			Total	Unique
	bp			
SMC222CG	167–214	4	3	1
SMC221MS	111–155	4	2	0
SMC179SA	115–219	12	5	0
SMC1493CL	105–169	11	8	0
mSSCIR14	205–258	7	5	1
mSSCIR53	163–246	7	4	2

Molecular Characterization

A genetic fingerprint of CPCL 05-1102 was developed with six pairs of microsatellite primers (Table 2) developed through the International Consortium for Sugarcane Biotechnology (Cordeiro et al., 2003). These results were compared with results of cultivars CP 72-2086, CP 78-1628, CP 80-1743, CP 84-1198 (Glaz et al., 1994), and CP 89-2143. The reaction conditions for the fragment analysis and polymerase chain reaction were as described by Glynn et al. (2009b) with some modifications. Specifically, thermocycling consisted of 95°C for 3 min, 6 cycles of 94°C for 45 s, 68°C for 5 min (decreasing by 2°C per cycle), 72°C for 1 min, 8 cycles of 94°C for 45 s, 58°C for 2 min (decreasing by 1°C per cycle), 72°C for 30 s, and 25 cycles of 94°C for 45 s, 50°C for 2 min, and 72°C for 30 s followed by a final extension of 72°C for 7 min. CPCL 05-1102 was also tested for the presence of *Bru*1, a major gene for resistance to brown rust of sugarcane (Daugrois et al., 1996; Asnaghi et al., 2004), according to the methods described by Glynn et al. (2012).

Disease Screening

Disease screening of CPCL 05-1102 was conducted by inoculation testing and/or monitoring for natural infection for *Sugarcane yellow leaf virus* (SCYLV), smut, mosaic, and leaf scald. Screening for brown and orange rust of CPCL 05-1102 was based only on natural infection in stage 4. The rating scale of each rust infection was as follows: 0 (resistant), 1 (moderately resistant), 2 (moderately susceptible), 3 (susceptible), and 4 (highly susceptible). These ratings were determined primarily on the size and number of uredia.

Leaves of CPCL 05-1102 were collected and preserved in plastic bags to assay for the presence of SCYLV. Tissue prints of the leaf midribs were made on nitrocellulose membranes, which were developed serologically as described by Comstock et al. (1999). These tissue prints were made on the same day that leaf samples were collected to assay for the presence of SCYLV.

Screening for mosaic by artificial inoculation was conducted in 2008 and 2009. Two replications of 30 single bud cuttings of CPCL 05-1102 along with 30 single bud cuttings of each of 39 other genotypes were planted in flats and grown in a greenhouse. CP 72-2086, which

is susceptible to mosaic and was grown on 1.2% of the commercial hectarage in Florida in 2011 (Rice et al., 2012), was used as a commercial reference in these tests. Seedlings of the sorghum [*Sorghum bicolor* (L.) Moench] cultivar Rio were grown in flats in a greenhouse and inoculated using an air brush at 551.6 kPa with a suspension of sugarcane mosaic virus E extracted from symptomatic sugarcane leaves. This sorghum cultivar is susceptible to sugarcane mosaic. One week after inoculation of the sorghum, when the sugarcane plants were about 15 cm tall, sorghum leaves were collected and ground to prepare fresh inocula, which were used to inoculate sugarcane plants with an air brush at 551.6 kPa. Sugarcane mosaic virus infection of the sugarcane was assessed 4 to 6 wk after inoculation.

Three replications of single bud cuttings of CPCL 05-1102 and 39 other genotypes were grown in flats in the greenhouse to test for their susceptibility to leaf scald in 2008 and 2009. The commercial reference was CP 80-1743, which is moderately susceptible to leaf scald and was grown on 5.0% of the commercial hectarage in Florida in 2011 (Rice et al., 2012). The single bud cuttings were inoculated by spraying their freshly cut ends with a painter's air brush attachment at 275.8 kPa and a suspension containing 108 cells mL^{-1} of *X. albilineans*. Plants were grown in the greenhouse for 10 to 12 wk and during the final 3 wk were assessed for symptoms of leaf scald infection.

Reaction to sugarcane smut was evaluated on CPCL 05-1102 plants in 2009 in a field inoculated test. Five stalk sections, with each section having three buds, of CPCL 05-1102 were immersed for 30 min in a suspension containing 106 smut spores mL^{-1}. Inoculated stalk sections were stored overnight under a plastic tarp and the following day they were planted in four replications of one-row plots, 5-m long. The number of infected stalks per plot was compared with the number of infected stalks of CP 78-1628 and CP 73-1547 (Miller et al., 1982), the reference cultivars, which were inoculated similarly. CP 73-1547 is no longer grown commercially, but CP 78-1628 was grown on 7.4% of the commercial hectarage in Florida in 2011 (Rice et al., 2012). The susceptibilities of CP 73-1547 and CP 78-1628 to smut are at the upper limits of acceptability for commercial production in Florida. Susceptibilities to mosaic, leaf scald, and smut were also rated on the basis of natural infection on plantings of CPCL 05-1102 in stage 4.

Field inoculation tests of ratoon stunt disease were conducted in 2007 and 2009. A single stalk of CPCL 05-1102 was inoculated at planting by cutting it with a machete that had been immersed in juice extracted from highly infected stalks. Stalks of a disease-free susceptible check, CP 72-1210, and a disease-free resistant check, CP 72-2086, were also inoculated. After 10 to 12 mo, a 25-cm long stalk section was sampled at the base of the plant from each of five stalks of each cultivar. Cores 1 cm in diameter of stalk tissue from internodes were extracted and imprinted onto nitrocellulose membranes. The number of vascular bundles colonized by bacteria was determined with a tissue blot immunoassay technique described by Comstock et al. (2001) and Harrison and Davis (1988).

Freeze Tolerance

To assess freeze tolerance, CPCL 05-1102, the reference cultivar CP 89-2143, and 18 other stage-4 genotypes were subjected to freezing temperatures in a field experiment planted at the Hague Farm (29°45.00′ N, 82°25.48′ W) of the Institute of Food and Agricultural Sciences, University of Florida, Hague, near Gainesville, FL on 26 Oct. 2010. Sugarcane growers in Florida consider that CP 89-2143 is one of a group of several cultivars that is most tolerant to freezes. The experiment was planted in a randomized complete block design with four replications in one-row plots 2.7 m long and 1.5 m apart with 2.4 m breaks between replications. Samples of five mature stalks were cut from each plot in the plant-cane crop on 9 and 30 Nov. 2011, and in 2012 on 6 and 25 January and 9 February. The 9 Nov. 2011 sampling was conducted before a freeze. Approximately 1 wk before each of the next four sampling dates, the following minimum temperatures and durations were recorded: –2.2 for 6 h (30 Nov. 2011), –7.8°C for 4 h and –2.8°C for 4 h (6 Jan. 2012), –2.8°C for 3 h (25 Jan. 2012), and –2.3°C for 2 h (9 Feb. 2012). All samples were transported to and stored at Canal Point under ambient conditions until juice was extracted by milling the cane 1 to 2 d later. Juice was subsequently analyzed for degrees Brix and optical rotation, and sucrose concentration was determined as described by Legendre (1992). Freeze-tolerance ratings were based on deterioration of the percentage of sucrose over time after exposure to freezing temperatures.

Statistical Analyses

Data generated from stage-4 tests were analyzed with the MIXED procedure of SAS (SAS Institute, 2008). Data were analyzed for each crop cycle separately and with the combined data across the plant-cane, first-ratoon, and second-ratoon crops. Within-year analyses used a mixed model with genotypes considered as fixed effects and locations and replications within locations considered as random effects. Across-year analyses used a mixed model with genotypes and crop cycles as fixed effects and locations and replications within locations considered as random effects. In this combined analysis, crop cycle and year were confounded. Differences among genotypes for stalk weight, stalk number, cane yield, CRS, sucrose yield, and economic index were declared significant by separating least square means with the LSD at $P \leq 0.05$. The LSD was used based on guidance by Saville (2013) and because we had concerns about excessive type II errors (Glaz and Dean, 1988). The unrestricted LSD is useful for researchers concerned about type II errors because, assuming all treatment means are equal, it does not decrease type I error rates (other procedures reduce type I error rates to levels $< \alpha$), and unlike other multiple comparison procedures, it does not cause substantial increases in type II error rates (Carmer and Swanson, 1971). The LSD values were computed as described by Saxton (1998). The data from north Florida for freeze tolerance were analyzed according to an additive main effects and multiplicative interaction (AMMI) model and the adjusted values were used to calculate the relative changes in percent sucrose as described by Edmé and Glaz (2013).

Characteristics

Field Performance

CPCL 05-1102 was tested in 19 harvests at seven trial locations in Florida during 2009–10 (five plant-cane harvests), 2010–11 (two plant-cane and five first-ratoon harvests), and 2011–12 (two first-ratoon and 5 second-ratoon harvests). The fiber concentration of CPCL 05-1102 was 101.7 g kg^{-1}.

Stalk weights of CPCL 05-1102 and CP 72-2086 were similar throughout the three-crop cycle (Table 3). However, in the plant-cane crop and for the mean of all three crop cycles, the stalk weight of CPCL 05-1102 was significantly heavier than that of CP 89-2143. The stalk numbers of CPCL 05-1102 and CP 89-2143 were similar throughout the three-crop cycle, and the stalk number of CPCL 05-1102 was significantly greater than that of CP 72-2086 in each crop except the plant-cane crop. The cane yields of CPCL 05-1102 and CP 89-2143 did not differ significantly throughout the three-crop cycle. Except in the plant-cane crop when there was no difference, the cane yield of CPCL 05-1102 was significantly greater than that of CP 72-2086.

The CRS values for CPCL 05-1102, CP 72-2086, and CP 89-2143 did not differ significantly in any crop cycle or for the mean across the three crops (Table 3). The sucrose yields of CPCL 05-1102 were significantly greater than those of CP 72-2086 in all crop cycles, and the sucrose yield of CPCL 05-1102 was significantly greater than that of CP 89-2143 in the plant-cane crop. Otherwise, the sucrose yields of CPCL 05-1102 and CP 89-2143 did not differ significantly. The economic indexes of CPCL 05-1102 and CP 89-2143 were similar across all crop cycles. The economic index of CPCL 05-1102 was significantly greater than that of CP 72-2086 in each comparison except in the plant-cane crop, where the economic index of each cultivar did not differ significantly.

As stated above, in the collaborative CP sugarcane cultivar development program in Florida, decisions to advance genotypes in the final three selection stages (stage 2–stage 4) are made by a committee of sugarcane farmers and scientists from public and private organizations. This committee also decides to recommend to the USDA-ARS and the University of Florida which promising sugarcane genotypes to release for commercial production in Florida. On 4 June 2012, this committee recommended to release CPCL 05-1102 because of its high cane and sucrose yields and its resistance to most major and minor sugarcane diseases found in Florida.

Table 3. Plant-cane, first-ratoon, and second-ratoon crop stalk weights, cane yields, commercial recoverable sucrose values, sucrose yields, and economic indexes of CPCL 05-1102 and reference cultivars CP 72-2086 and CP 89-2143 planted on muck soils at seven locations.

	Crop cycle			
Cultivar	Plant cane	First ratoon	Second ratoon	Mean
	Stalk weight (kg)			
CPCL 05-1102	1.96 a†	1.54 a	1.37 a	1.63 a
CP 72-2086	1.89 a	1.45 a	1.25 a	1.56 ab
CP 89-2143	1.72 b	1.52 a	1.28 a	1.49 bc
	Stalk number (stalks ha^{-1}) × 1000			
CPCL 05-1102	82.93 ab	94.63 a	77.65 a	85.21 a
CP 72-2086	77.74 b	78.70 b	59.20 b	71.88 b
CP 89-2143	87.28 a	101.36 a	82.38 a	90.34 a
	Cane yield (Mg ha^{-1})			
CPCL 05-1102	161.73 a	144.40 a	97.42 a	135.56 a
CP 72-2086	144.44 a	117.29 b	73.88 b	111.56 b
CP 89-2143	150.70 a	144.24 a	101.98 a	133.46 a
	Commercial recoverable sucrose (g kg^{-1})			
CPCL 05-1102	120.74 a	125.31 a	113.20 a	120.28 a
CP 72-2086	120.36 a	122.97 a	110.91 a	118.23 a
CP 89-2143	119.39 a	121.89 a	114.87 a	119.77 a
	Sucrose yield (Mg ha^{-1})			
CPCL 05-1102	19.56 a	18.25 a	11.16 a	16.54 a
CP 72-2086	17.50 b	14.43 b	8.38 b	16.17 b
CP 89-2143	18.08 b	17.88 a	11.85 a	13.45 a
	Economic index ($ ha^{-1})			
CPCL 05-1102	3645 a	3383 a	1604 a	2933 a
CP 72-2086	3203 a	2562 b	1134 b	2313 b
CP 89-2143	3299 a	3260 a	1743 a	2829 a
Locations	7	7	5	

†For each characteristic, means within a column followed by the same letter are not significantly different based on LSD test at $P \leq 0.05$.

Agronomic, Botanical, and Molecular Descriptions

Differences in growth, environment, and cultural conditions are known to cause changes in phenotypic expression in sugarcane cultivars without any change in the genotype. Therefore, readers are cautioned that phenotypic traits reported here for CPCL 05-1102 may not remain consistent across locations and years.

Growth cracks were absent on the stalks of CPCL 05-1102 or CP 89-2143 (Table 4). The mean stalk height, which was measured from the ground to the top visible dewlap (dewlaps form the hinge of the blade joint in sugarcane), of 10 stalks was 359 cm for CPCL 05-1102 compared with 271 cm for CP 89-2143 (Table 4). The stalks of CPCL 05-1102 were mostly green-yellow (2.5GY7/8) where the stalks were exposed and yellow (5Y8/4) under the leaf sheaths. The mean internode length of 10 stalks of CPCL 05-1102 at the fifth internode from the ground was 15.5 cm compared with 11.8 cm for CP 89-2143. Stalk diameter was measured at the middle of the 2nd (low), 5th (low middle) and 10th (upper middle) internodes from the ground as well as at the middle of the hardened internode closest to the top visible dewlap (upper) on 10 stalks. The mean low, lower-middle, upper-middle, and upper stalk diameters of CPCL 05-1102 were 29.4, 27.7, 28.7, and 20.7 mm, respectively, compared with diameters for CP 89-2143 of 30.5, 29.9, 27.6, and 20.7 mm, respectively.

CPCL 05-1102 exhibited a cylindrical internode and a growth ring with a mean width of 2.8 mm at the fifth internode from the ground (Table 4). The root band of CPCL 05-1102 was 7.5 mm wide. No bud furrows were observed on

Table 4. Botanical descriptions and colors of sugarcane cultivar CPCL 05-1102 and reference cultivar CP 89-2143 as determined in a field planting at Eastgate Farms, Inc. near Pahokee, FL.

Trait†	CPCL 05-1102	CP 89-2143
Growth cracks	Absent	Few, length of internode and shallow
Stalk height (cm)	359	271
Exposed stalk color	Green-yellow (2.5GY7/8)	Green-yellow (2.5GY7/6)
Stalk color under leaf sheath	Yellow (5Y8/4)	Yellow (5Y8/4)
Internode length (cm)	15.5	11.8
Stalk diameter (mm)		
Low (2nd internode)	29.4	30.5
Low-middle (5th internode)	27.7	29.9
Upper-middle (10th internode)	28.7	27.6
Uppermost	24.7	20.7
Internode shape	Cylindrical	Concave/convex
Growth ring width (mm)	2.8	2.3
Root band width (mm)	7.5	6.1
Bud furrows	Absent	Absent
Bud color	Yellow and green yellow (5Y8/4 and 2.5GY7/8)	Yellow (5Y8/4)
Stalk bud shape	Round bud with central germ pore	Round bud with central germ pore
Stalk bud length (mm)	7.6	6.1
Stalk bud width (mm)	7.9	6.5
Leaf sheath pubescence	Mostly absent, but sparse pubescence near center of sheath	Absent
Leaf length (cm)	143.6	176.7
Leaf width (mm)	45.7	39.9
Leaf midrib color	Green-yellow (5GY5/4)	Green-yellow (5GY6/6)
Dewlap (leaf collar) shape	Squarish deltoid	Narrow double crescent
Short auricle shape	Absent	Absent
Long auricle shape	Long lanceolate	Short lanceolate
Long auricle length (mm)	20.9	5.2
Auricle color	Yellow-red (7.5YR8/4)	Yellow (2.5Y8/4)
Ligule shape	Broad crescent	Crescent with lozenge

†Data are means of 10 stalks measured on 1 and 2 August. Internode length, bud width and length, root band width, growth ring width measured at fifth node from ground. Color codes from *Munsell Color Charts for Plant Tissues.*

CPCL 05-1102 or CP 89-2143. The buds of CPCL 05-1102 were yellow (5Y8/4) and green-yellow (2.5GY7/8) compared with yellow (5Y8/4) buds on the stalks of CP 89-2143. Buds of both CPCL 05-1102 and CP 89-2143 were raised above the surface of the root band, although the buds of CPCL 05-1102 were raised more prominently than those of CP 89-2143. The buds of both cultivars were shaped as described by Artschwager and Brandes (1958)—round with a central germ pore at the fifth internode from the ground. The means for bud length and width of the fifth bud from the bottom from five stalks of CPCL 05-1102 were 7.6 and 7.9 mm; the length and width means of CP 89-2143 buds were 6.1 and 6.5 mm. Pubescence was mostly absent on the leaf sheaths of CPCL 05-1102 except for sparse pubescence near the sheath centers. The buds of CPCL 05-1102 had no pubescence except for light pubescence on the bud wings. There was no pubescence on the leaf sheaths or buds of CP 89-2143.

The leaf blade length and width means of CPCL 05-1102 at the top visible dewlap were 143.6 cm and 46 mm (Table 4). These compared with leaf blade length and width means of 176.7 cm and 40 mm for CP 89-2143. The mean midrib widths of CPCL 05-1102 and CP 89-2143 at the widest part of the leaf at the top visible dewlap on the adaxial side were 6.5 and 5.0 mm. The midrib of CPCL 05-1102 was green-yellow (5GY5/4); the midrib of CP 89-2143 was a similar shade of green-yellow (5GY6/6).

According to the terminology of Artschwager and Brandes (1958), CPCL 05-1102 dewlaps were squarish deltoid in shape compared with the narrow double crescent shape of the CP 89-2143 dewlaps (Table 4). Auricles, which were only on one side of the stalk of CPCL 05-1102, were yellow-red (7.5YR8/4) and long lanceolate in shape. CP 89-2143 stalks also had auricles only on one side of the stalks, and these auricles were short lanceolate in shape and yellow (2.5Y8/4). The mean lengths of the auricles measured four nodes below the top visible dewlap for CPCL 05-1102 and CP 89-2143 were 20.9 and 5.2 mm. The leaf ligules of CPCL 05-1102 were broad crescent in shape, whereas the leaf ligules of CP 89-2143 were crescent with lozenge.

The six microsatellite primer pairs amplified 27 fragments, ranging from 105 to 258 bp in CPCL 05-1102 (Table 2). The number of fragments amplified by each primer pair ranged from 2 to 8. Of the 27 fragments amplified, 22 were polymorphic and 5 were monomorphic among the six cultivars. CPCL 05-1102 shared 16 fragments with CP 78-1628, 17 with CP 72-2086, 12 with CP 89-2143, 17 with CP 84-1198, and 13 with CP 80-1743. Fragments unique to CPCL 05-1102 were identified in the fingerprints obtained using primer pairs SMC222CG (211 bp), mSSCIR14 (236 bp), and mSSCIR53 (219 bp and 233 bp).

Disease Reactions

Based on evaluations of natural infection, CPCL 05-1102 was determined to be resistant (rating = 0) to the brown and orange rust pathogens (Table 5). *Bru*1 is a major gene for brown rust resistance in sugarcane (Daugrois et al., 1996; Asnaghi et al., 2004; Glynn et al., 2012), but it was not detected in the DNA of CPCL 05-1102. This finding indicates that the resistance of CPCL 05-1102 to brown rust is from a genetic source other than *Bru1*. CPCL 05-1102

Table 5. Disease reactions and presence (+) or absence (–) of *Bru*1 gene in sugarcane cultivar CPCL 05-1102 and reference cultivars CP 72-2086, CP 78-1628, and CP 89-2143 in Florida.

Cultivar	Brown rust	*Bru*1	Orange rust	*Sugarcane yellow leaf virus*	Smut	Leaf scald	Mosaic	Ratoon stunt
CPCL 05-1102	R†	–	R	S	R	R	R	MS
CP 72-2086	MR	+	S	R	R	R	S	R
CP 78-1628	S	–	MS	MS	S	MS	R	MS
CP 89-2143	R	+	S	MS	R	MS	MS	MS

†R, resistant; MR, moderately resistant; MS, moderately susceptible; S, susceptible.

was classified as susceptible to SCYLV, as are most other CP genotypes and commercial sugarcane cultivars in Florida (Comstock et al., 1999).

In smut inoculation tests conducted in 2009, 0.0, 0.3, and 0.5 sori per plot were observed on CPCL 05-1102, CP 73-1547 and CP 78-1628, respectively. During its 4 yr of testing in stage 4, no smut sori resulting from natural infection were observed on CPCL 05-1102, whereas 60 sori were observed on CP 78-1628. On the basis of these data from artificial and natural inoculation, CPCL 05-1102 is considered to be resistant to smut (Table 5).

CPCL 05-1102 had 0.7 and 7.6% of plants infected with leaf scald compared with 37.8 and 20.7% for CP 80-1743 in 2008 and 2009, respectively. Only one plant of CPCL 05-1102 was observed as naturally infected with leaf scald during its 4 yr of testing in stage 4 at seven locations. CP 80-1743 was not included in these stage-4 tests. Based on these comparisons with inoculated CP 80-1743 and the almost nonexistent natural infection of CPCL 05-1102 to leaf scald (one infected plant in six plots per location at seven locations, growing at each location for 3 yr), CPCL 05-1102 is considered to be resistant to leaf scald (Table 5). CPCL 05-1102 had no plants infected with mosaic compared with 66.4 and 31.0% plants of CP 72-2086 infected with mosaic in 2008 and 2009, respectively. No plants of CPCL 05-1102 were observed to be naturally infected with mosaic during the 4 yr of its stage-4 testing. On the basis of these results, CPCL 05-1102 is classified as resistant to mosaic.

CPCL 05-1102 produced mean colonized vascular bundle counts of 7.0 and 11.6 in 2007 and 2009, respectively, in inoculation tests for ratoon stunt. These compared with counts of 9.9 and 2.8 for CP 72-1210 in 2007 and 2009, respectively. On the basis of these tests, CPCL 05-1102 was classified as moderately susceptible to ratoon stunt (Table 5). Ratoon stunt, however, can be controlled by the use of uninfected planting material, which can be purchased commercially, or can be achieved through thermal treatment (Damann and Benda, 1983). Dean and Davis (1990) reported that ratoon stunt caused 5% reductions in sucrose yields in Florida in fields that had not received thermal treatment. Comstock (2008) reported that ratoon stunt infections caused reductions in stalk number, cane yield, and sucrose yield. These reductions were not always significant, but the trends were consistent.

Freeze Tolerance

CP 89-2143 is a sugarcane cultivar in Florida that is considered to have excellent freeze tolerance. During the first three sampling dates that followed freezes (30 Nov. 2011 and 6 and 25 Jan. 2012), the freeze tolerance of CPCL 05-1102 was outstanding. During this period, the CRS of CPCL 05-1102 ranged from 4.6 to 6.1 g kg^{-1} more than that of CP 89-2143, and the CRS of CPCL 05-1102 averaged 5.5 g kg^{-1} more than that of CP 89-2143. However, by the final sampling date (9 Feb. 2012), the CRS of CPCL 05-1102 had dropped substantially: it was 14.6 g kg^{-1} less than that of CP 89-2143. Thus, defining the freeze tolerance of CPCL 05-1102 is complex. We conclude that CPCL 05-1102 has outstanding freeze tolerance to moderate freeze temperatures (> –3°C). For harsher freezes, such as the –7.8°C that occurred before the 6 Jan. 2012 sampling, the freeze tolerance of CPCL 05-1102 remained outstanding for about 2 wk (at least up until 25 Jan. 2012), but deteriorated later, and by 9 Feb. 2012 it had become poor. It is rare in south Florida for sugarcane to be exposed for long durations to temperatures of < –5°C.

Conclusions

CPCL 05-1102 is a new sugarcane cultivar with sucrose yields and an economic index on muck soils in Florida that should be advantageous for growers. CPCL 05-1102 is resistant to most of the major sugarcane diseases in Florida. The resistance to brown rust exhibited by CPCL 05-1102 is not due to the major brown rust resistance gene *Bru*1, indicating that CPCL 05-1102 is exhibiting a different genetic source of resistance to this pathogen.

Availability

In its initial year of release, seed cane of CPCL 05-1102 will be available from the Florida Sugar Cane League, Inc. for commercial planting in Florida. It is not anticipated that a plant patent for CPCL 05-1102 will be sought. Small quantities of seed cane for research purposes may be obtained at the USDA-ARS Sugarcane Field Station, Canal Point, FL where CPCL 05-1102 will be maintained for at least 5 yr from the date of this publication.

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